National Semiconductor

January 1995

LM150, LM350A/LM350 3-Amp Adjustable Regulators

General Description

The LM150 series of adjustable 3-terminal positive voltage regulators is capable of supplying in excess of 3A over a 1.2V to 33V output range. They are exceptionally easy to use and require only 2 external resistors to set the output voltage. Further, both line and load regulation are comparable to discrete designs. Also, the LM150 is packaged in standard transistor packages which are easily mounted and handled.

In addition to higher performance than fixed regulators, the LM150 series offers full overload protection available only in IC's. Included on the chip are current limit, thermal overload protection and safe area protection. All overload protection circuitry remains fully functional even if the adjustment terminal is accidentally disconnected.

Normally, no capacitors are needed unless the device is situated more than 6 inches from the input filter capacitors in which case an input bypass is needed. An output capacitor can be added to improve transient response, while bypassing the adjustment pin will increase the regulator's ripple rejection.

Besides replacing fixed regulators or discrete designs, the LM150 is useful in a wide variety of other applications. Since the regulator is "floating" and sees only the input-to-output differential voltage, supplies of several hundred volts can be regulated as long as the maximum input to output differential is not exceeded, i.e., avoid short-circuiting the output.

By connecting a fixed resistor between the adjustment pin and output, the LM150 can be used as a precision current regulator. Supplies with electronic shutdown can be achieved by clamping the adjustment terminal to ground which programs the output to 1.2V where most loads draw little current.

The part numbers in the LM150 series which have a K suffix are packaged in a standard Steel TO-3 package, while those with a T suffix are packaged in a TO-220 plastic package. The LM150 is rated for $-55°C \leq T_J \leq +150°C$, while the LM350A is rated for $-40°C \leq T_J \leq +125°C$, and the LM350 is rated for $0°C \leq T_J \leq +125°C$.

Features

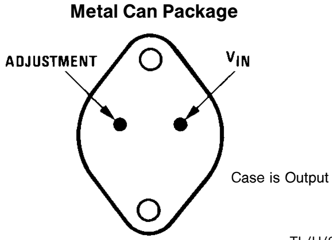
- Adjustable output down to 1.2V
- Guaranteed 3A output current
- Guaranteed thermal regulation
- Output is short circuit protected
- Current limit constant with temperature
- P^+ Product Enhancement tested
- 86 dB ripple rejection
- Guaranteed 1% output voltage tolerance (LM350A)
- Guaranteed max. 0.01%/V line regulation (LM350A)
- Guaranteed max. 0.3% load regulation (LM350A)

Applications

- Adjustable power supplies
- Constant current regulators
- Battery chargers

Connection Diagrams

(TO-3 STEEL)
Metal Can Package



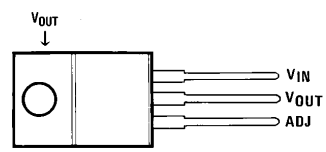
TL/H/9061–4

Bottom View

Order Number LM150K STEEL or LM350K STEEL
See NS Package Number K02A

Order Number LM150K/883
See NS Package Number K02C

(TO-220)
Plastic Package



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Front View

Order Number LM350AT or LM350T
See NS Package Number T03B

Absolute Maximum Ratings

If Military/Aerospace specified devices are required, please contact the National Semiconductor Sales Office/Distributors for availability and specifications. (Note 4)

Power Dissipation	Internally Limited
Input-Output Voltage Differential	+35V
Storage Temperature	−65°C to +150°C
Lead Temperature	
Metal Package (Soldering, 10 sec.)	300°C
Plastic Package (Soldering, 4 sec.)	260°C
ESD Tolerance	TBD
Operating Temperature Range	
LM150	$-55°C \leq T_J \leq +150°C$
LM350A	$-40°C \leq T_J \leq +125°C$
LM350	$0°C \leq T_J \leq +125°C$

Electrical Characteristics

Specifications with standard type face are for $T_J = 25°C$, and those with **boldface type** apply over **full Operating Temperature Range.** Unless otherwise specified, $V_{IN} - V_{OUT} = 5V$, and $I_{OUT} = 10$ mA. (Note 2)

Parameter	Conditions	LM150			Units
		Min	Typ	Max	
Reference Voltage	$3V \leq (V_{IN} - V_{OUT}) \leq 35V$, $10\ mA \leq I_{OUT} \leq 3A$, $P \leq 30W$	**1.20**	**1.25**	**1.30**	V
Line Regulation	$3V \leq (V_{IN} - V_{OUT}) \leq 35V$ (Note 3)		0.005	0.01	%/V
			0.02	**0.05**	%/V
Load Regulation	$10\ mA \leq I_{OUT} \leq 3A$ (Note 3)		0.1	0.3	%
			0.3	**1**	%
Thermal Regulation	20 ms Pulse		0.002	0.01	%/W
Adjustment Pin Current			**50**	**100**	μA
Adjustment Pin Current Change	$10\ mA \leq I_{OUT} \leq 3A$, $3V \leq (V_{IN} - V_{OUT}) \leq 35V$		**0.2**	**5**	μA
Temperature Stability	$T_{MIN} \leq T_J \leq T_{MAX}$		**1**		%
Minimum Load Current	$V_{IN} - V_{OUT} = 35V$		**3.5**	**5**	mA
Current Limit	$V_{IN} - V_{OUT} \leq 10V$ $V_{IN} - V_{OUT} = 30V$	**3.0** 0.3	**4.5** 1		A A
RMS Output Noise, % of V_{OUT}	$10\ Hz \leq f \leq 10\ kHz$		0.001		%
Ripple Rejection Ratio	$V_{OUT} = 10V$, f = 120 Hz, $C_{ADJ} = 0\ \mu F$		**65**		dB
	$V_{OUT} = 10V$, f = 120 Hz, $C_{ADJ} = 10\ \mu F$	**66**	**86**		dB
Long-Term Stability	$T_J = 125°C$, 1000 hrs		0.3	1	%
Thermal Resistance, Junction to Case	K Package		1.2	1.5	°C/W
Thermal Resistance, Junction to Ambient (No Heat Sink)	K Package		35		°C/W

Electrical Characteristics (Continued)

Specifications with standard type face are for $T_J = 25°C$, and those with **boldface type** apply over **full Operating Temperature Range.** Unless otherwise specified, $V_{IN} - V_{OUT} = 5V$, and $I_{OUT} = 10$ mA. (Note 2) (Continued)

Parameter	Conditions	LM350A			LM350			Units
		Min	Typ	Max	Min	Typ	Max	
Reference Voltage	$I_{OUT} = 10$ mA, $T_J = 25°C$	1.238	1.250	1.262				V
	$3V \leq (V_{IN} - V_{OUT}) \leq 35V$, 10 mA $\leq I_{OUT} \leq 3A$, $P \leq 30W$	**1.225**	**1.250**	**1.270**	**1.20**	**1.25**	**1.30**	V
Line Regulation	$3V \leq (V_{IN} - V_{OUT}) \leq 35V$ (Note 3)		0.005	0.01		0.005	0.03	%/V
			0.02	**0.05**		**0.02**	**0.07**	%/V
Load Regulation	10 mA $\leq I_{OUT} \leq 3A$ (Note 3)		0.1	0.3		0.1	0.5	%
			0.3	**1**		**0.3**	**1.5**	%
Thermal Regulation	20 ms Pulse		0.002	0.01		0.002	0.03	%/W
Adjustment Pin Current			**50**	**100**		**50**	**100**	μA
Adjustment Pin Current Change	10 mA $\leq I_{OUT} \leq 3A$, $3V \leq (V_{IN} - V_{OUT}) \leq 35V$		**0.2**	**5**		**0.2**	**5**	μA
Temperature Stability	$T_{MIN} \leq T_J \leq T_{MAX}$		**1**			**1**		%
Minimum Load Current	$V_{IN} - V_{OUT} = 35V$		**3.5**	**10**		**3.5**	**10**	mA
Current Limit	$V_{IN} - V_{OUT} \leq 10V$	**3.0**	**4.5**		**3.0**	**4.5**		A
	$V_{IN} - V_{OUT} = 30V$	0.3	1		0.25	1		A
RMS Output Noise, % of V_{OUT}	10 Hz $\leq f \leq$ 10 kHz		0.001			0.001		%
Ripple Rejection Ratio	$V_{OUT} = 10V$, f = 120 Hz, $C_{ADJ} = 0$ μF		**65**			**65**		dB
	$V_{OUT} = 10V$, f = 120 Hz, $C_{ADJ} = 10$ μF	**66**	**86**		**66**	**86**		dB
Long-Term Stability	$T_J = 125°C$, 1000 hrs		0.25	1		0.25	1	%
Thermal Resistance, Junction to Case	K Package					1.2	1.5	°C/W
	T Package		3	4		3	4	°C/W
Thermal Resistance, Junction to Ambient (No Heat Sink)	K Package					35		°C/W
	T Package		50			50		°C/W

Note 1: Absolute Maximum Ratings indicate limits beyond which damage to the device may occur. Operating Ratings indicate conditions for which the device is intended to be functional, but do not guarantee specific performance limits. For guaranteed specifications and test conditions, see the Electrical Characteristics.

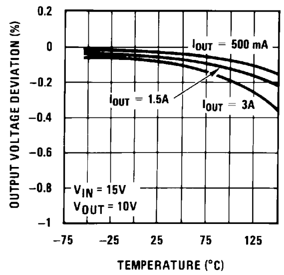
Note 2: These specifications are applicable for power dissipations up to 30W for the TO-3 (K) package and 25W for the TO-220 (T) package. Power dissipation is guaranteed at these values up to 15V input-output differential. Above 15V differential, power dissipation will be limited by internal protection circuitry. All limits (i.e., the numbers in the Min. and Max. columns) are guaranteed to National's AOQL (Average Outgoing Quality Level).

Note 3: Regulation is measured at a constant junction temperature, using pulse testing with a low duty cycle. Changes in output voltage due to heating effects are covered under the specifications for thermal regulation.

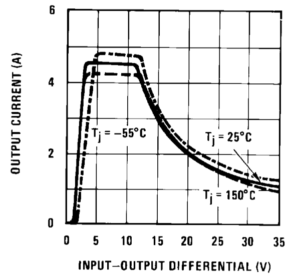
Note 4: Refer to RETS150K drawing for military specifications of the LM150K.

Typical Performance Characteristics

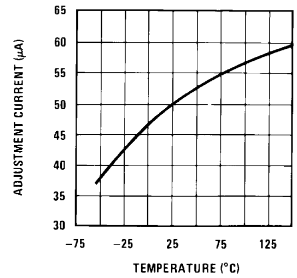
Load Regulation



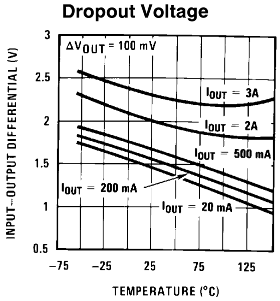
Current Limit



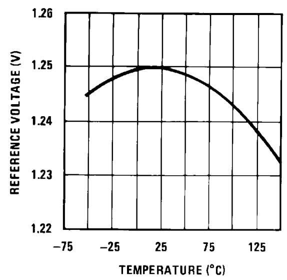
Adjustment Current



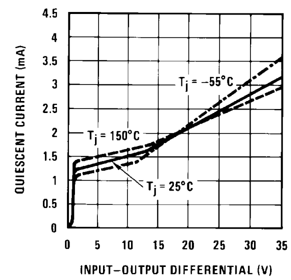
Dropout Voltage



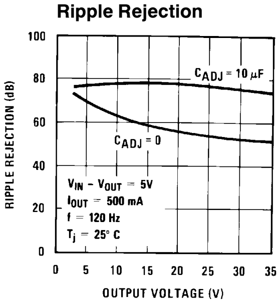
Temperature Stability



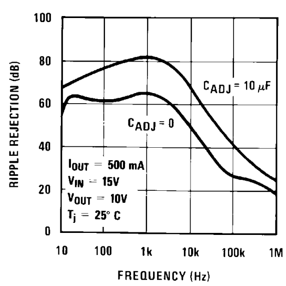
Minimum Operating Current



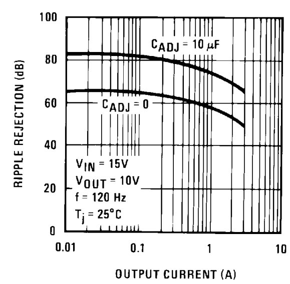
Ripple Rejection



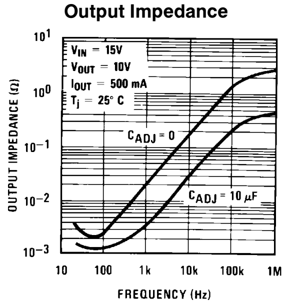
Ripple Rejection



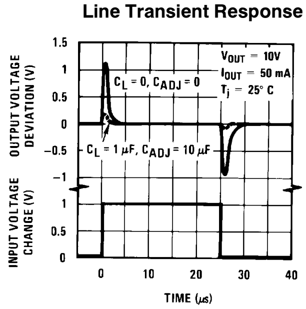
Ripple Rejection



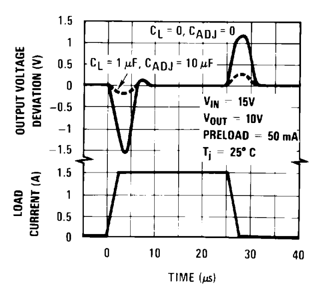
Output Impedance



Line Transient Response



Load Transient Response

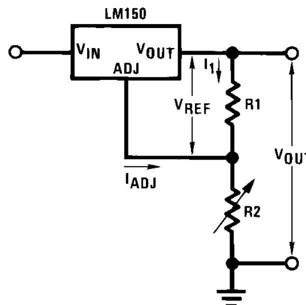


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Application Hints

In operation, the LM150 develops a nominal 1.25V reference voltage, V_{REF}, between the output and adjustment terminal. The reference voltage is impressed across program resistor R1 and, since the voltage is constant, a constant current I_1 then flows through the output set resistor R2, giving an output voltage of

$$V_{OUT} = V_{REF}\left(1 + \frac{R2}{R1}\right) + I_{ADJ}\,R2.$$



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FIGURE 1

Since the 50 μA current from the adjustment terminal represents an error term, the LM150 was designed to minimize I_{ADJ} and make it very constant with line and load changes. To do this, all quiescent operating current is returned to the output establishing a minimum load current requirement. If there is insufficient load on the output, the output will rise.

EXTERNAL CAPACITORS

An input bypass capacitor is recommended. A 0.1 μF disc or 1 μF solid tantalum on the input is suitable input bypassing for almost all applications. The device is more sensitive to the absence of input bypassing when adjustment or output capacitors are used but the above values will eliminate the possibility of problems.

The adjustment terminal can be bypassed to ground on the LM150 to improve ripple rejection. This bypass capacitor prevents ripple from being amplified as the output voltage is increased. With a 10 μF bypass capacitor 86 dB ripple rejection is obtainable at any output level. Increases over 10 μF do not appreciably improve the ripple rejection at frequencies above 120 Hz. If the bypass capacitor is used, it is sometimes necessary to include protection diodes to prevent the capacitor from discharging through internal low current paths and damaging the device.

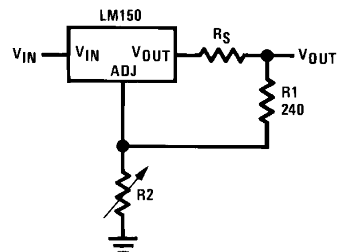
In general, the best type of capacitors to use is solid tantalum. Solid tantalum capacitors have low impedance even at high frequencies. Depending upon capacitor construction, it takes about 25 μF in aluminum electrolytic to equal 1 μF solid tantalum at high frequencies. Ceramic capacitors are also good at high frequencies, but some types have a large decrease in capacitance at frequencies around 0.5 MHz. For this reason, 0.01 μF disc may seem to work better than a 0.1 μF disc as a bypass.

Although the LM150 is stable with no output capacitors, like any feedback circuit, certain values of external capacitance can cause excessive ringing. This occurs with values between 500 pF and 5000 pF. A 1 μF solid tantalum (or 25 μF aluminum electrolytic) on the output swamps this effect and insures stability.

LOAD REGULATION

The LM150 is capable of providing extremely good load regulation but a few precautions are needed to obtain maximum performance. The current set resistor connected between the adjustment terminal and the output terminal (usually 240Ω) should be tied directly to the output (case) of the regulator rather than near the load. This eliminates line drops from appearing effectively in series with the reference and degrading regulation. For example, a 15V regulator with 0.05Ω resistance between the regulator and load will have a load regulation due to line resistance of 0.05Ω × I_{OUT}. If the set resistor is connected near the load the effective line resistance will be 0.05Ω (1 + R2/R1) or in this case, 11.5 times worse.

Figure 2 shows the effect of resistance between the regulator and 240Ω set resistor.



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FIGURE 2. Regulator with Line Resistance in Output Lead

With the TO-3 package, it is easy to minimize the resistance from the case to the set resistor, by using two separate leads to the case. The ground of R2 can be returned near the ground of the load to provide remote ground sensing and improve load regulation.

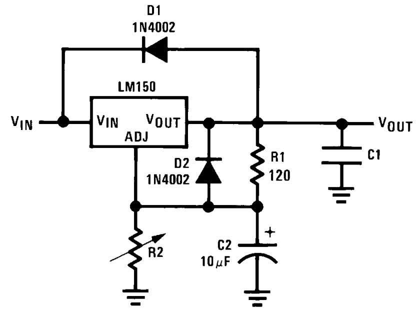
PROTECTION DIODES

When external capacitors are used with *any* IC regulator it is sometimes necessary to add protection diodes to prevent the capacitors from discharging through low current points into the regulator. Most 10 μF capacitors have low enough internal series resistance to deliver 20A spikes when shorted. Although the surge is short, there is enough energy to damage parts of the IC.

When an output capacitor is connected to a regulator and the input is shorted, the output capacitor will discharge into the output of the regulator. The discharge current depends on the value of the capacitor, the output voltage of the regulator, and the rate of decrease of V_{IN}. In the LM150, this discharge path is through a large junction that is able to sustain 25A surge with no problem. This is not true of other types of positive regulators. For output capacitors of 25 μF or less, there is no need to use diodes.

The bypass capacitor on the adjustment terminal can discharge through a low current junction. Discharge occurs when *either* the input or output is shorted. Internal to the LM150 is a 50Ω resistor which limits the peak discharge current. No protection is needed for output voltages of 25V or less and 10 μF capacitance. *Figure 3* shows an LM150 with protection diodes included for use with outputs greater than 25V and high values of output capacitance.

Application Hints (Continued)



D1 protects against C1

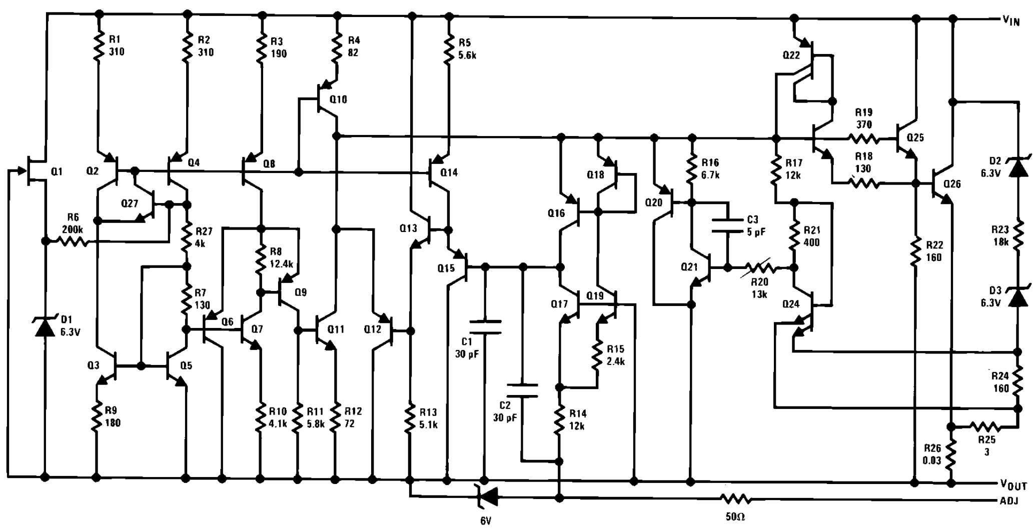
D2 protects against C2

$$V_{OUT} = 1.25V \left(1 + \frac{R2}{R1}\right) + I_{ADJ}R2$$

TL/H/9061–9

FIGURE 3. Regulator with Protection Diodes

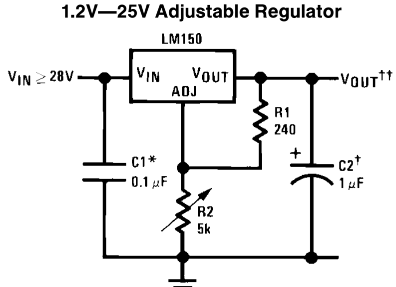
Schematic Diagram



TL/H/9061–10

Typical Applications

1.2V—25V Adjustable Regulator



TL/H/9061–1

Full output current not available at high input-output voltages.

†Optional—improves transient response. Output capacitors in the range of 1 µF to 1000 µF of aluminum or tantalum electrolytic are commonly used to provide improved output impedance and rejection of transients.

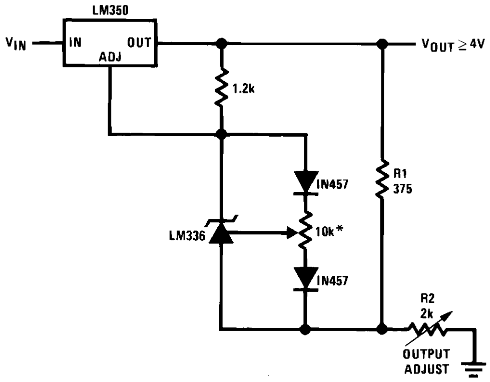
*Needed if device is more than 6 inches from filter capacitors.

$$††V_{OUT} = 1.25V \left(1 + \frac{R2}{R1}\right) + I_{ADJ}\,(R2)$$

Note: Usually R1 = 240Ω for LM150 and R1 = 120Ω for LM350.

Typical Applications (Continued)

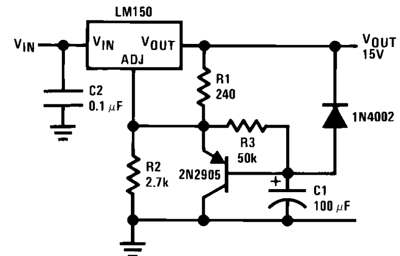
Precision Power Regulator with Low Temperature Coefficient



*Adjust for 3.75V across R1

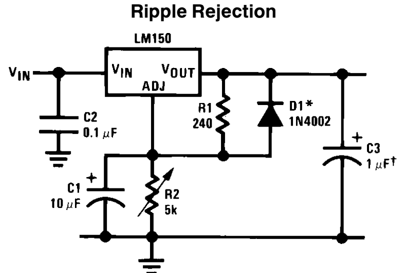
TL/H/9061–13

Slow Turn-ON 15V Regulator



TL/H/9061–14

Adjustable Regulator with Improved Ripple Rejection

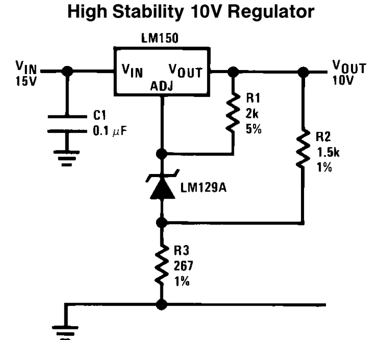


†Solid tantalum

TL/H/9061–15

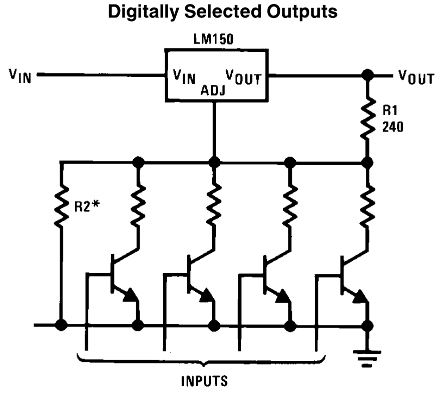
*Discharges C1 if output is shorted to ground

High Stability 10V Regulator



TL/H/9061–16

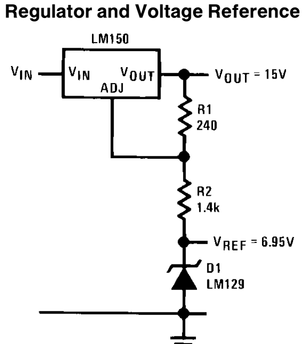
Digitally Selected Outputs



TL/H/9061–17

*Sets maximum V_{OUT}

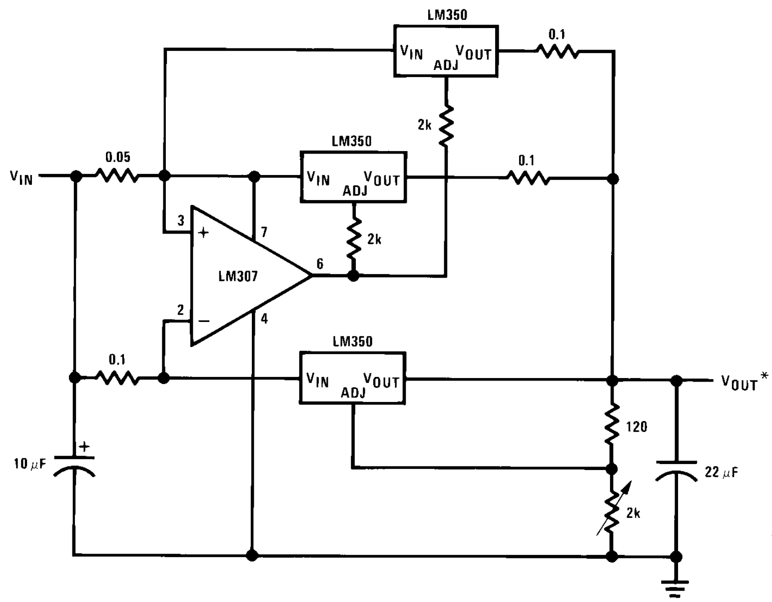
Regulator and Voltage Reference



TL/H/9061–3

Typical Applications (Continued)

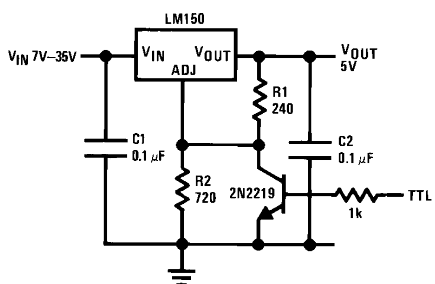
10A Regulator



*Minimum load current 50 mA

TL/H/9061–18

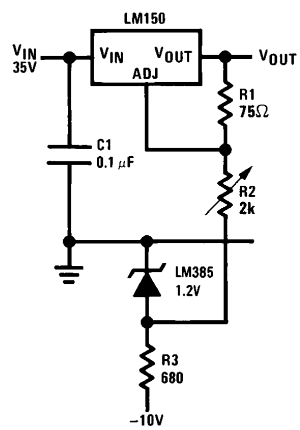
5V Logic Regulator with Electronic Shutdown*



TL/H/9061–19

*Min output ≈ 1.2V

0 to 30V Regulator

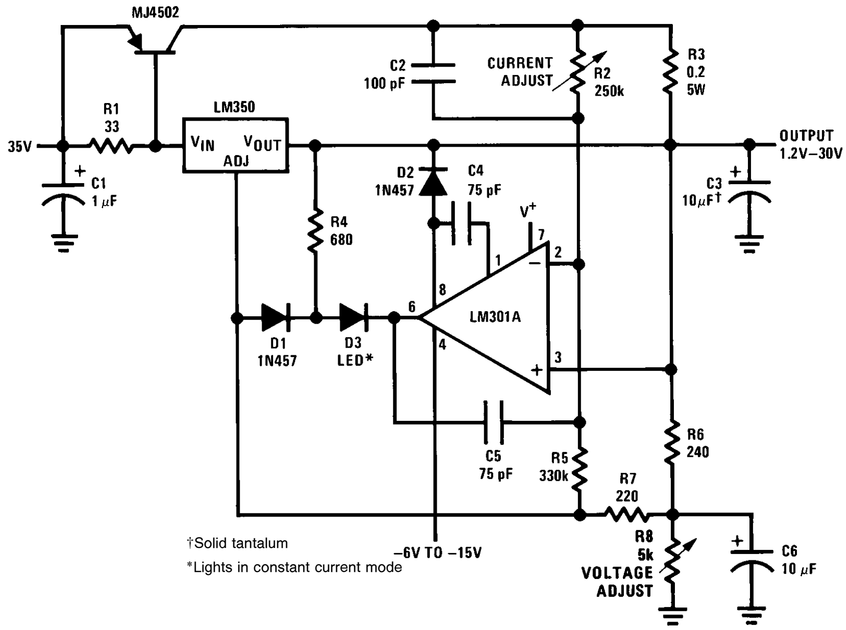


TL/H/9061–20

Full output current not available at high input-output voltages

Typical Applications (Continued)

5A Constant Voltage/Constant Current Regulator

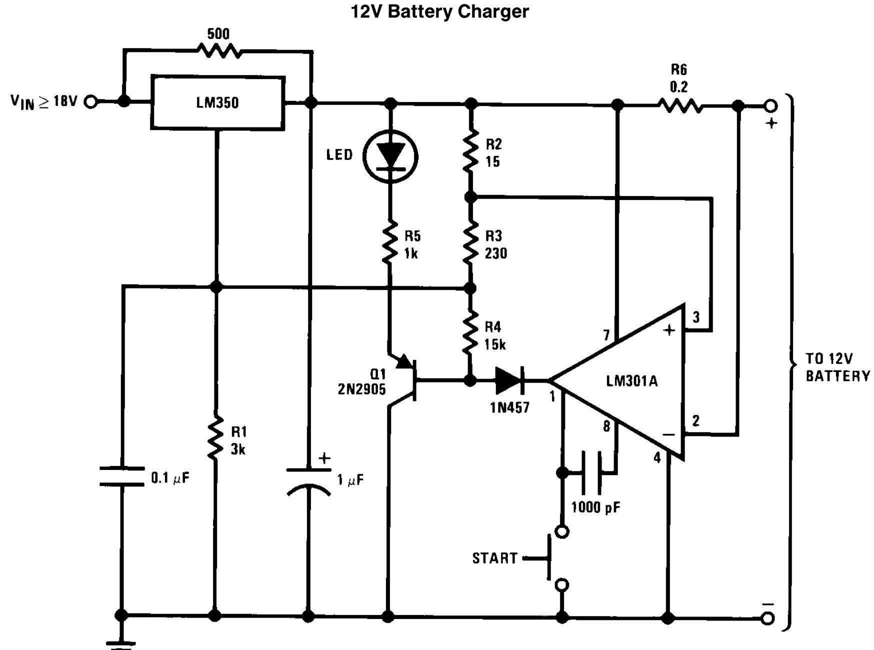


†Solid tantalum

*Lights in constant current mode

TL/H/9061–21

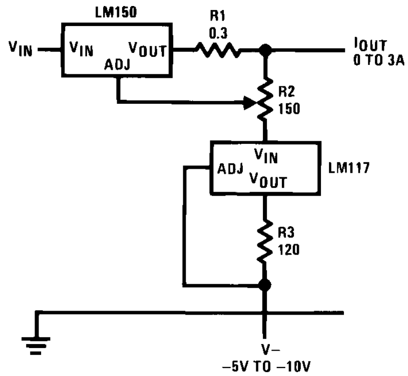
12V Battery Charger



TL/H/9061–22

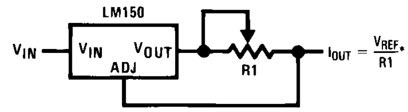
Typical Applications (Continued)

Adjustable Current Regulator



TL/H/9061–23

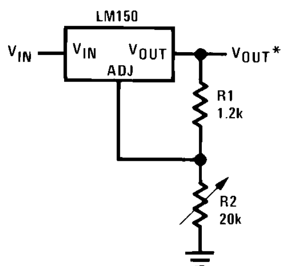
Precision Current Limiter



TL/H/9061–24

$*0.4 \leq R_1 \leq 120\Omega$

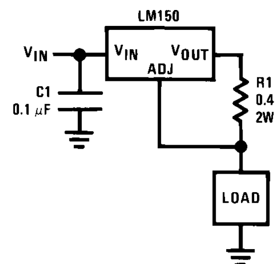
1.2V–20V Regulator with Minimum Program Current



TL/H/9061–25

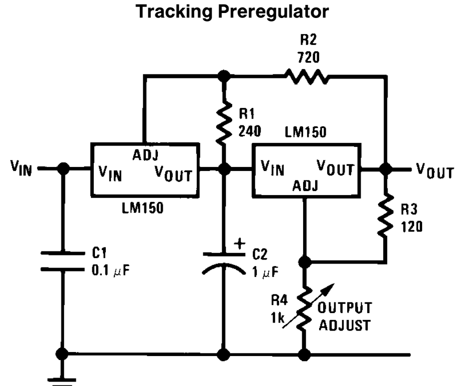
*Minimum output current ≈ 4 mA

3A Current Regulator



TL/H/9061–26

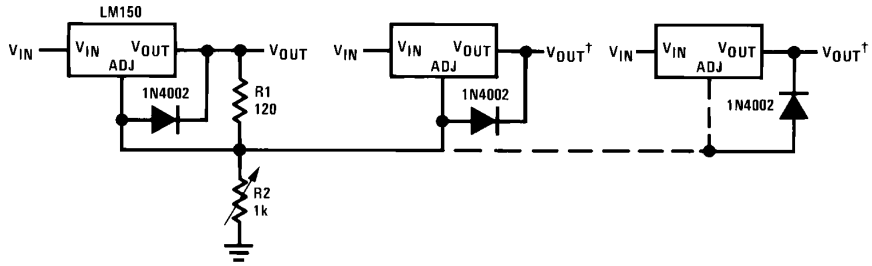
Tracking Preregulator



TL/H/9061–27

Typical Applications (Continued)

Adjusting Multiple On-Card Regulators with Single Control*

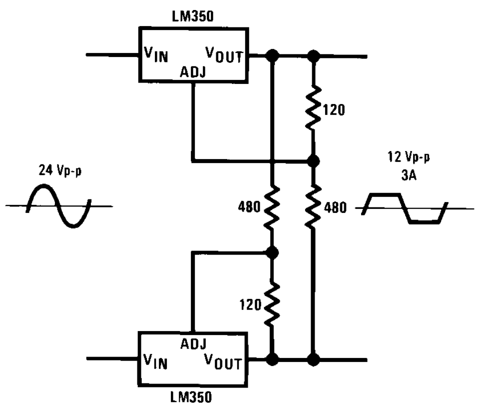


TL/H/9061–28

†Minimum load—10 mA

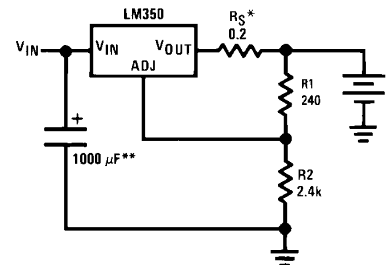
*All outputs within ±100 mV

AC Voltage Regulator



TL/H/9061–29

Simple 12V Battery Charger



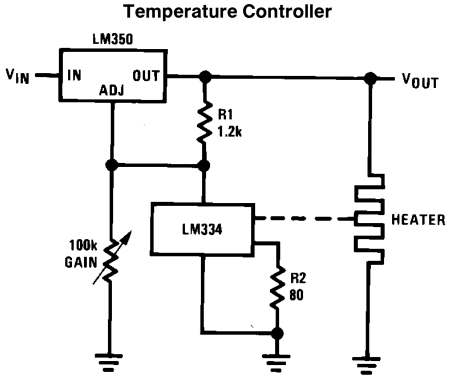
TL/H/9061–30

*R_S—sets output impedance of charger: $Z_{OUT} = R_S \left(1 + \frac{R2}{R1}\right)$

Use of R_S allows low charging rates with fully charged battery.

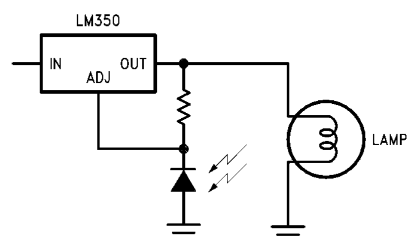
**1000 μF is recommended to filter out any input transients

Temperature Controller



TL/H/9061–11

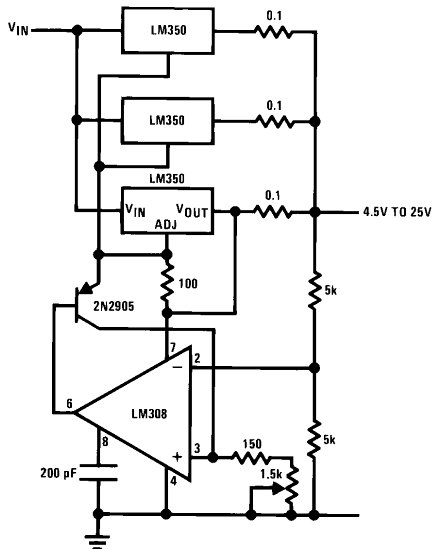
Light Controller



TL/H/9061–12

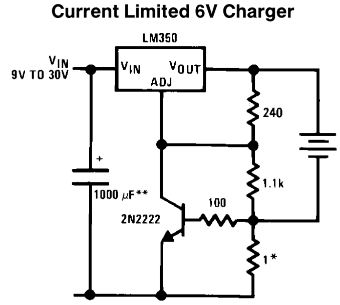
Typical Applications (Continued)

Adjustable 10A Regulator



TL/H/9061–31

Current Limited 6V Charger

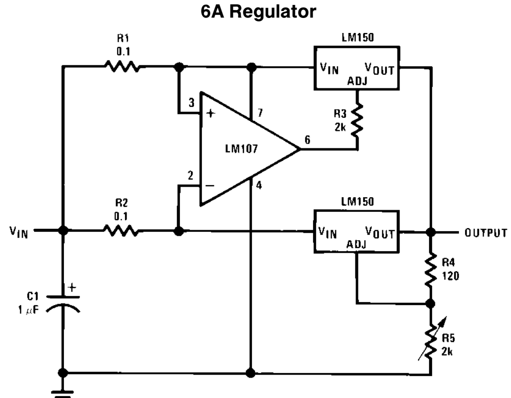


TL/H/9061–32

*Sets peak current (2A for 0.3Ω)

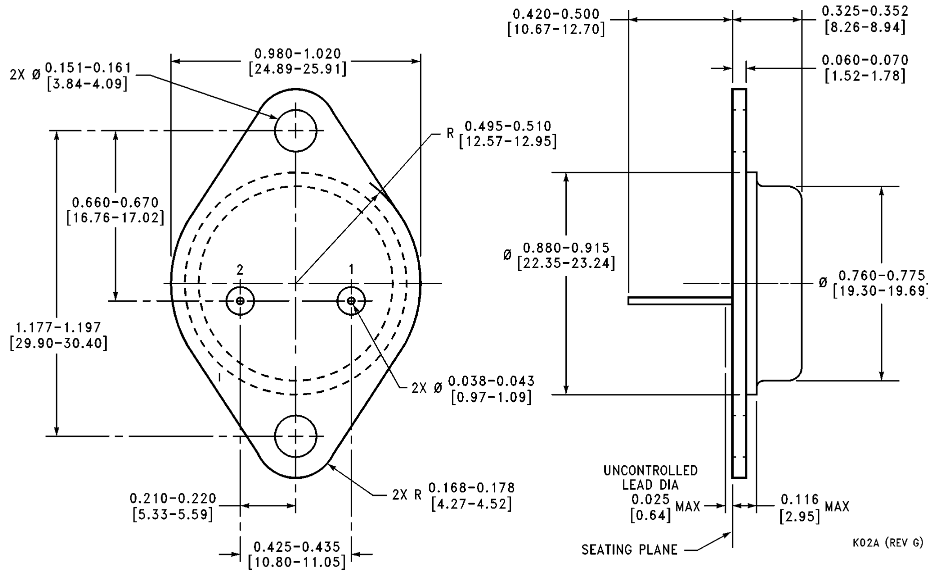
**1000 μF is recommended to filter out any input transients.

6A Regulator

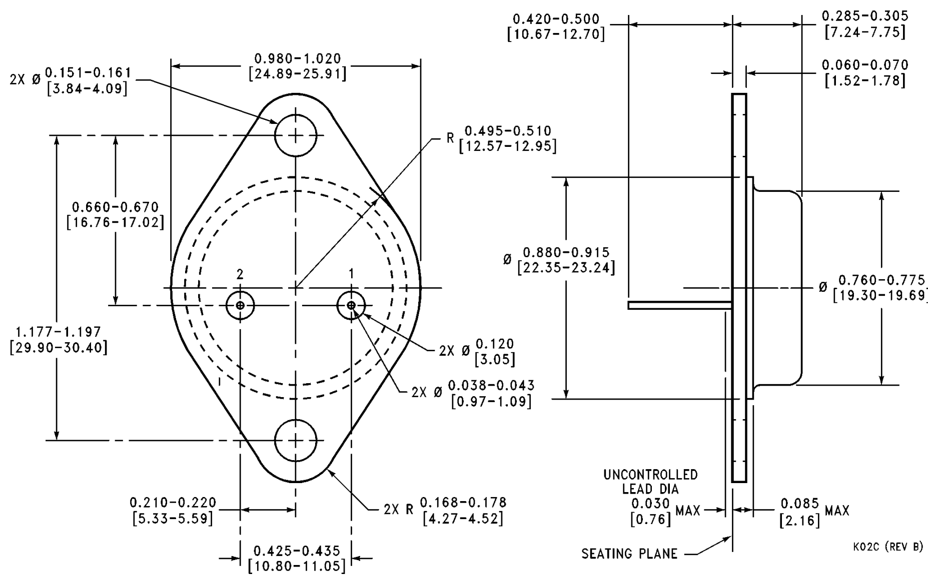


TL/H/9061–2

Physical Dimensions inches (millimeters)

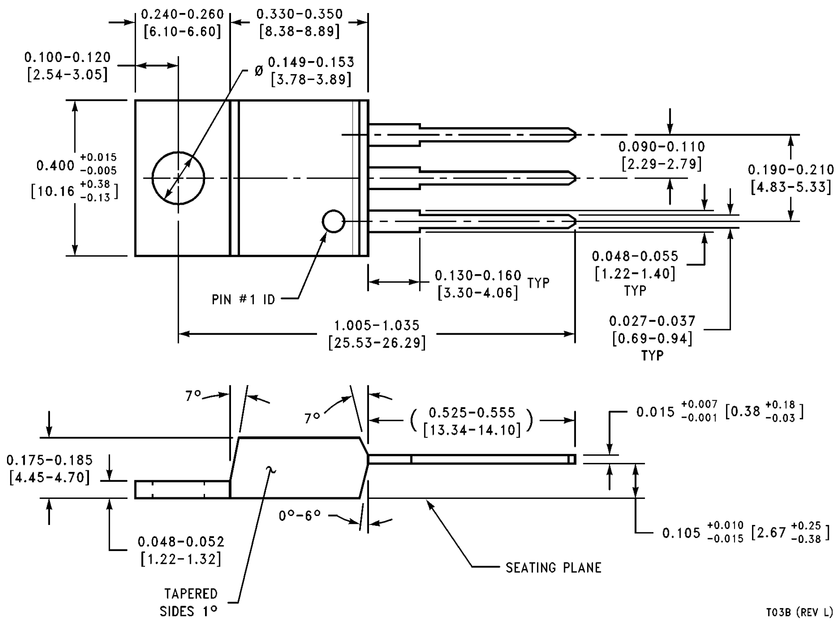


2 Lead TO-3 Metal Can Package (K)
Order Number LM150K STEEL or LM350K STEEL
NS Package Number K02A



2 Lead TO-3 Metal Can Package (K)
Mil-Aero Product
Order Number LM150K/883
NS Package Number K02C

Physical Dimensions inches (millimeters) (Continued)



3 Lead Molded TO-220 (T)
Order Number LM350AT or LM350T
NS Package Number T03B

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